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THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

Dendroctonus monticolae Hopk.
(Coleoptera:Scolytidae)

PROGRESS REPORT - STUDY II

Studies of Populations

By

Walter E. Cole
Entomologist

Prepared by

DIVISION OF FOREST INSECT RESEARCH
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Joseph F. Pechanec, Director
Forest Service
U.S. Department of Agriculture
Ogden, Utah

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SUMMARY

1. Egg distribution by inch of gallery followed a skewed curve with the peak deposition between the second and fourth inches of gallery.

2. Egg deposition was uniform by height within a tree but varied by gallery between plots.

3. Egg deposition decreased with an increase in attack density.

4. Brood mortality, due to intraspecific competition alone, increased with attack density. Emergence ratios and total mortality reacted inversely and directly, respectively, with attack density.

5. Population increases or decreases reacted proportionally to the parasite-predator complex--on a host insect: parasite-predator ratio basis.

6. Life tables are presented for the study plots and compared with the previous year's data. Explanation of mortality rates and causes are attempted.

7. Population trends are discussed in relation to the "concentration-dilution" of brood theory and the number of infested trees.

INTRODUCTION

The project program is basically a study in the population dynamics of the mountain pine beetle in lodgepole pine. This study is restricted to populations of test insects inhabiting specific areas. Insect populations are rarely stable in number and, therefore, this study is focused on determining the forces of change, their quality, frequency, magnitude, and mode of action.

Three study plots are now established: (1) Wasatch--an old, continuing epidemic infestation; (2) Teton--a recurrent or cyclic infestation, now in its peak; and (3) Caribou--a new rapidly developing infestation.

This progress report covers the second generation year of study, fall 1962 through summer 1963, of the population dynamics of the mountain pine beetle.

OBJECTIVES

There were four objectives for the generation year 1962-1963. They were to:

1. Determine egg deposition distribution by height in tree, by study plot based on eggs per total gallery; average number of eggs per inch of gallery; and by each inch of gallery.

2. Expand the competition phase to include a greater range of attack densities and to determine mortality within and between galleries.

3. Determine host insect: parasite-predator ratios.

4. Continue compiling and expand life tables for the study plots.

RESULTS

1. Egg deposition.--Sample trees were felled and billets were cut at alternate 14-inch intervals until height of infestation was reached. Average number of billets per plot were: (1) Caribou, 7 (16 ft.); (2) Teton 8 (19 ft.); and (3) Wasatch, 4 (9 ft.). Only galleries complete within the billet were measured for length and number of eggs. The number of eggs, niches, or starts of larval galleries were recorded by first, second, third, etc., inches of gallery.

The average egg gallery length per area proved to be a good basis for further comparisons (1) Caribou = 6.71 inches, (2) Teton = 6.95 inches; and (3) Wasatch = 5.82 inches.

Egg distribution within the gallery followed similar patterns for the Teton and Wasatch, but sporadic deposition occurred on the Caribou plot (fig. 1). If this sporadic egg deposition was due to other than sampling error, then age of infestation (more vigorous female beetles) is the main variable not common to the Teton and Wasatch. The Caribou infestation is in its third year of existence and second year of increasing population. Attack densities per 1/4 square foot were: Caribou (3.75), Teton (1.56), and Wasatch (3.00). It is unlikely that attack density would cause the difference in egg deposition pattern between the Caribou and the other two infestations. Probably the most important influence would be the moisture content of the cambium (Reid 1962). The Caribou plot is more moist and contains greater diameter trees with much thicker bark than either the Teton or Wasatch plots.

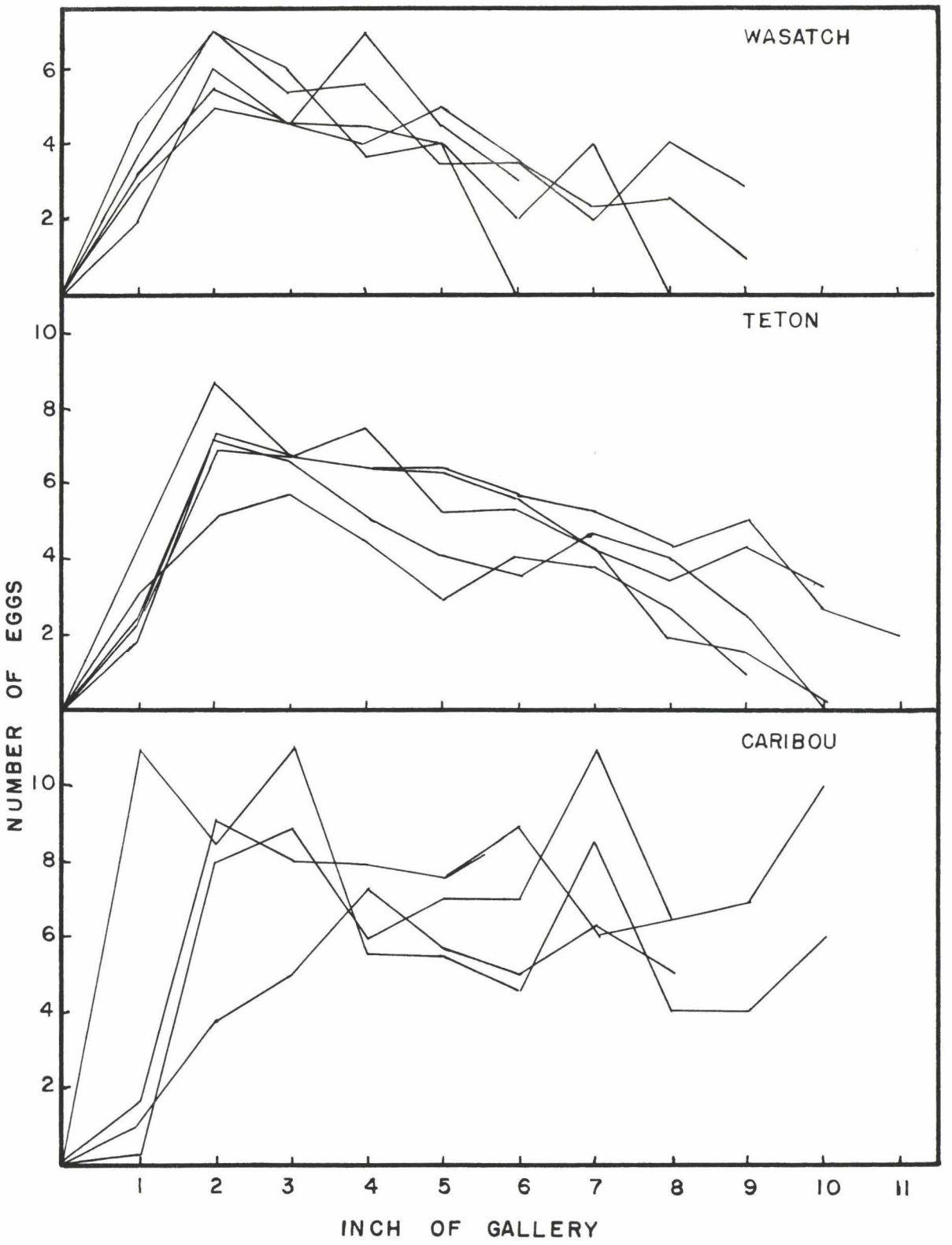

Figure 1.--Egg deposition by inch of gallery, by height in tree, by study plot.

The analysis of variance was computed, using both eggs per gallery and average eggs per inch of gallery, to determine if differences existed in these populations between study plots and within study trees. For both bases, differences in egg populations were shown by study plot--and for both bases the Caribou egg population caused the variation. Egg deposition was uniform by height in tree--no significant difference. Only for eggs per gallery was the interaction, area x height, significant--there was no uniformity in egg deposition by gallery between corresponding heights by area (tables 1 and 2).

Table 1.--Average eggs per gallery for study plots and heights in tree.

Study Plots		
Caribou	Teton	Wasatch
40.54	31.66	27.00

Height in Tree			
Log 1 (low)	Log 2	Log 3	Log 4 (high)
37.23	29.57	31.88	37.69

Height in Tree				
Plot	Log 1	Log 2	Log 3	Log 4
Caribou	53.60	31.56	36.20	33.50
Teton	25.00	29.78	32.50	43.57
Wasatch	31.40	23.00	25.25	25.50

Underline indicates measurement causing variation or difference.

Table 2.--Average eggs per inch of gallery for study plots and heights in tree.

Study Plots

Caribou	Teton	Wasatch
5.85	4.78	4.26

Heights in Tree

Log 1 (low)	Log 2	Log 3	Log 4
5.11	5.16	4.85	5.17

Heights in Tree

Plot	Log 1 (low)	Log 2	Log 3	Log 4
Caribou	6.47	5.81	5.68	4.63
Teton	4.21	4.62	4.98	5.65
Wasatch	4.37	4.81	3.57	4.57

A tendency to pattern was shown for the eggs per inch in the last section of table 2--that is deposition decreased by height on the Caribou, increased by height for the Teton; and remained fairly uniform (slight fluctuation) for the Wasatch. Annual measurements of the variable egg deposition pattern may be a partial indicator of population trend.

2. Intraspecific competition.--Experiments in intraspecific competition were continued. Techniques were identical to those previously reported (Cole 1962) with the exception of using more attack densities--1, 3, 6, 9, 12, 15, and 18 per square foot.

Measurements were increased to include egg deposition, early and late larval and pupal stages, new adults and mortality within and between broods.

Egg deposition decreased with attack density as did the resulting broods. The brood reduction was inversely proportional to total mortality (table 3 and fig. 2).

Table 3.--Mountain pine beetle brood populations and total mortality by attack density.

Attack Density	Brood Stages: Egg	Early larval	Late larval and pupal	New adults	Total mortality (percent)
1	50.00	46.00	46.00	39.00	22.00
3	28.33	17.00	17.00	15.33	45.88
6	11.06	7.84	5.62	4.06	63.29
9	8.39	6.28	4.22	3.50	58.28
12	9.21	7.46	4.75	3.21	65.15
15	12.04	10.80	6.69	4.51	62.55
18	10.15	8.89	5.56	2.39	76.45

Mortality within broods decreased with incresed attack density while mortality between broods increased proportionally with attack density. This latter case was to be expected; however, the within mortality curve can probably be best explained by the increasing difficulty in determining within brood mortality as attack density increases. A more or less constant within brood mortality was expected. On the other hand, egg deposition decreased with an increase in attack density; therefore, less within brood competition could be expected during the early larval population (fig. 3).

The emergence ratio (new adults: parent adults) and the total mortality reacted as expected in relationship to attack density--less emergence and greater mortality with increased attack density.

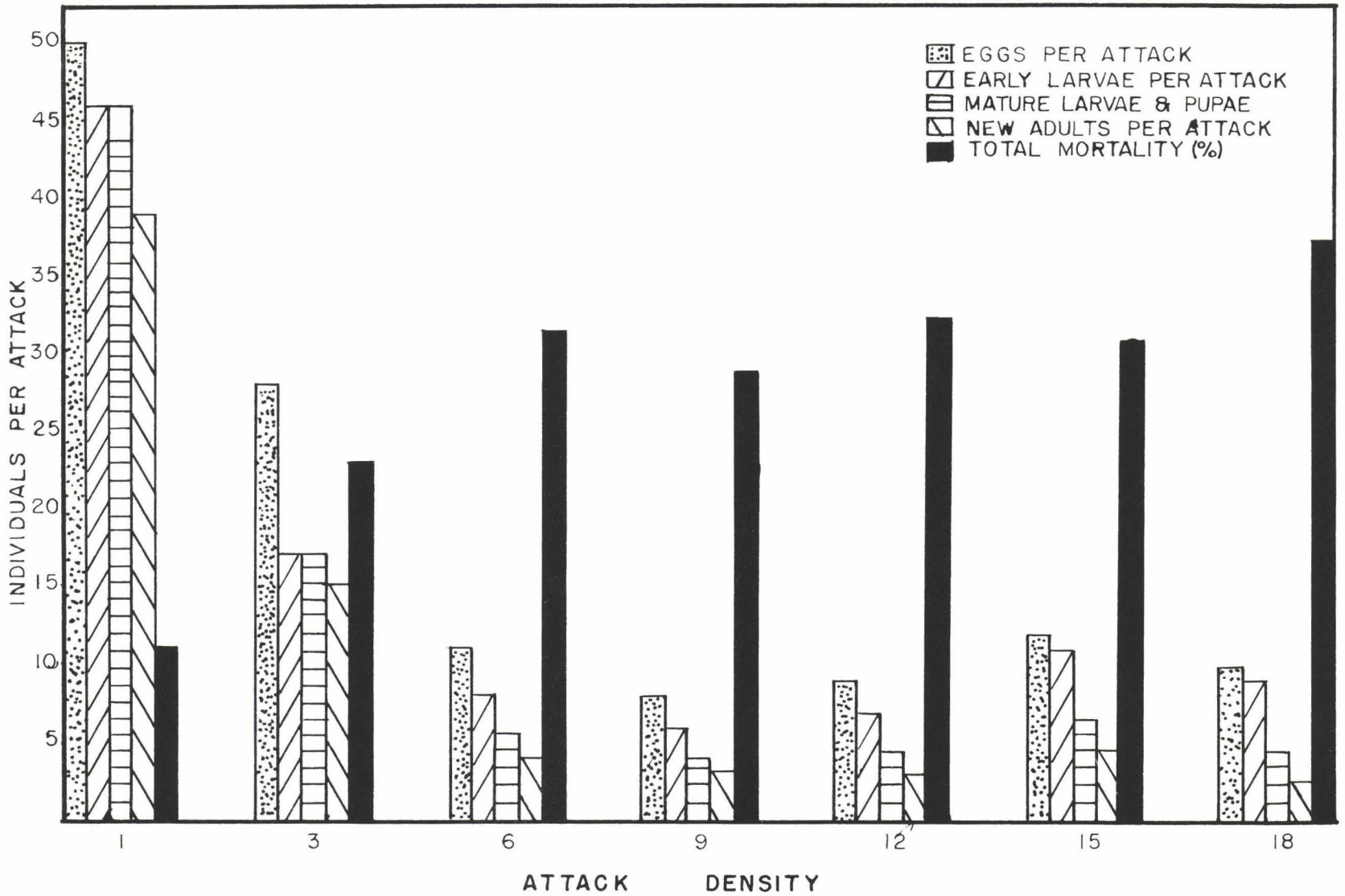
EGGS PER ATTACK
EARLY LARVAE PER ATTACK
MATURE LARVAE & PUPAE
NEW ADULTS PER ATTACK
TOTAL MORTALITY (%)
INDIVIDUALS PER ATTACK
50
45
40
35
30
25
20
15
10
5
1
3
6
9
12
15
18
ATTACK DENSITY

Figure 2.

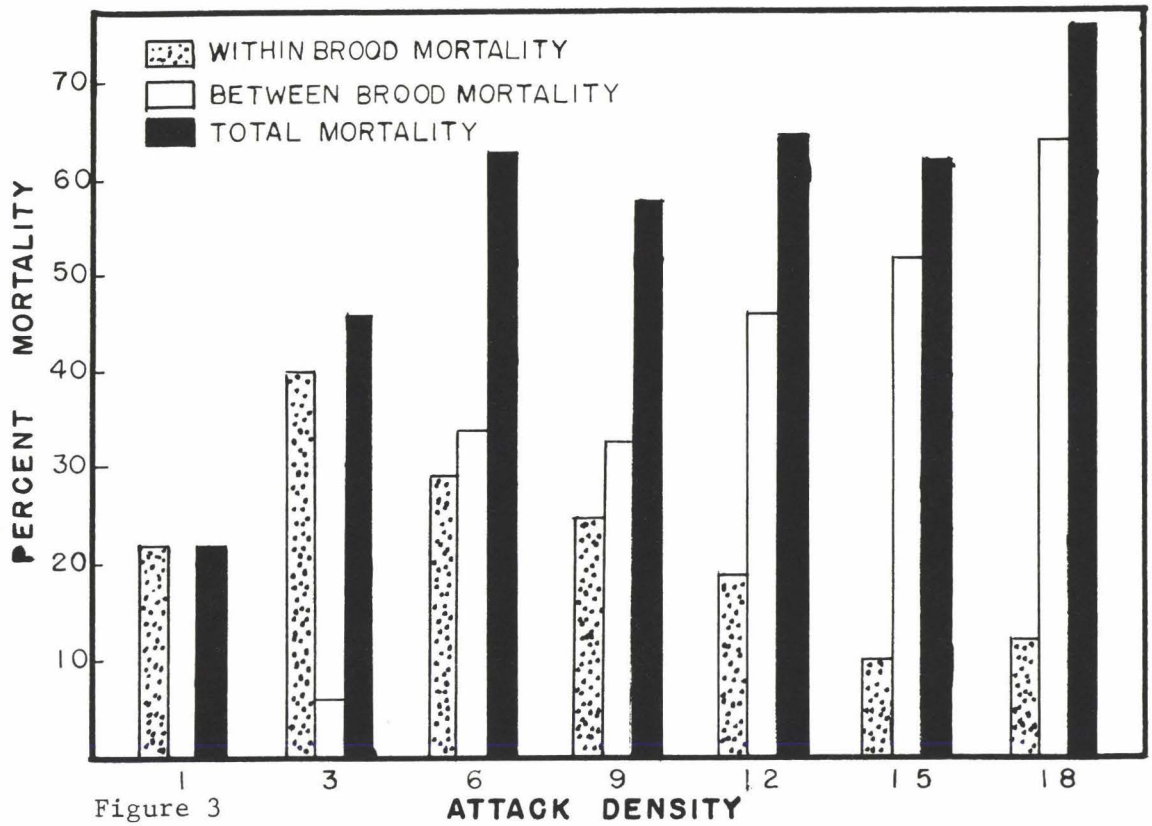

Figure 3

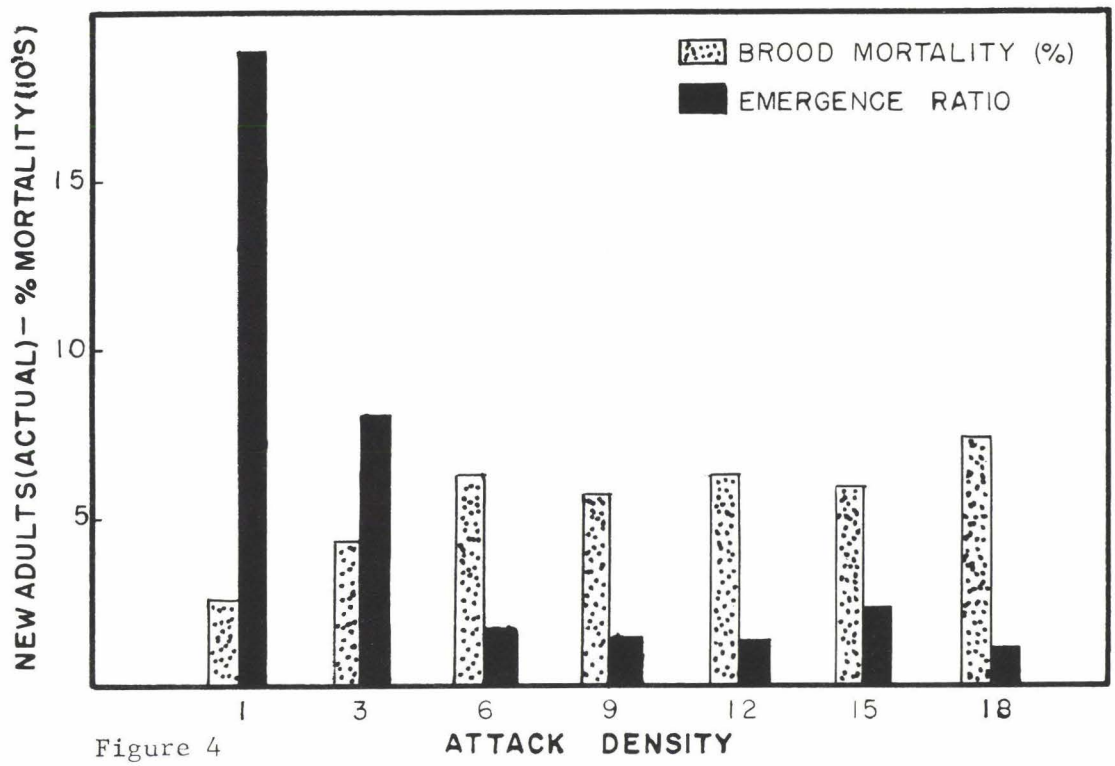

Figure 4

3. Parasites and Predators - Host insect ratios.--Distribution differences and correlations of the parasite-predator population with the host insect and secondary host insects are discussed in the progress report for Sampling Procedures (Cole 1964). Specimens recorded are shown in table 4.

Table 4.--Host insects, secondary host insects, parasites and predators, recorded by study plot (6- x 6-inch samples).

Species	Study Plot		
	Caribou	Teton	Wasatch
D. monticolae	30.50	16.25	10.40
Ips spp.	7.25	7.80	0.64
Pityogenes sp.	1.55	4.70	37.55
Epuraea linearis	0.30	0.20	0.60
Staphylinidae	0.10	0.25	5.86
Cleridae	0.15	0.10	0.20
Medetera sp.	0.05	0	0.20
Coeloides dendroctoni	0.05	1.35	0.55
Woodpecker work (sq. in.)	4.06	5.91	5.65
Coleopterous assoc.	8.80	13.50	39.19
Coleopterous predators	0.60	0.85	1.75
Dipterans	0.05	0	0.20
Hymenoptera	0.05	1.35	0.50
Total parasites-predators	0.70	2.10	7.40
Total host-secondaries	39.30	29.75	49.59

These populations occurred in parasite-predators to host insect ratios of: Caribou, 1:43.57; Teton, 1:7.74; Wasatch, 1:1.41. Much depends on the particular species and their effectiveness, singly and/or in combination, but the gross picture of ratios could indicate another reason for the continued increase of the Caribou mountain pine beetle population.

4. Life tables.--Periodic sampling of the populations provided data for the construction of life tables. All data refers to the population within a 6- x 6-inch sample. The life tables for the generation year 1961-1962 were based on one-square-foot samples. Comparisons of the two years necessitated converting the 1961-1962 data to a 1/4-square-foot basis.

There was no apparent resumption of egg laying in the spring for any of the three study plots this year as there was for the Teton in 1961-1962. The only reduction that approached catastrophic proportion was an extreme cold air movement through the Teton plot causing above normal winter mortality. Life tables for the study are shown in the following tables:

Table 5.--Life table for the mountain pine beetle on the Caribou plots for generation year 1962-1963.

Sample period	No. alive at start of x (per 1/4 sq.ft.)	Factors responsible for dx	No. dying during x (per 1/4 sq.ft.)	100 qx dx as pct. of 1_x
(x)	(1_x)	(d_xf)	(d_x)	
0	7.50	(parent adults)		
1	64.50	competition, weather	32.50	50.00
2	32.50	winter	3.50	10.08
3	No sample taken			
4.	29.00	predators, parasites, competition	3.62	12.48
5	25.38	" "	3.09	12.17
6	22.29	(new adults)		65.44

(197.20% increase from parent to new adult)

Table 6.--Life table for the mountain pine beetle on the Teton plot for generation year 1962-1963.

Sample period	No. alive at start of x (per 1/4 sq.ft.)	Factors responsible for dx	No. dying during x (per 1/4 sq.ft.)	100 qx dx as pct. of l_x
(x)	(l_x)	($d_x f$)	(d_x)	
0	3.12	(parent adults)		
1	66.00	competition, weather	57.62	87.30
2	8.38	winter	5.00	59.67
3	3.38	predators, competition	2.44	72.19
4	0.94	predators, parasites, competition	0.44	46.81
5	0.50	parasites, predators	0.44	88.00
6	0.06			99.91

(98.08% decrease from parent to new adult.)

Table 7.--Life table for the mountain pine beetle on the Wasatch plots for generation year 1962-1963.

Sample period (x)	No. alive at start of x (per 1/4 sq.ft.) (l_x)	Factors responsible for dx (d_xf)	No. dying during x (per 1/4 sq.ft.) (d_x)	100 qx dx as pct. of l_x
		Lower Wasatch		
0	5.80			
1	43.50	competition, weather	28.19	64.80
2	15.31	winter	4.56	29.78
3	10.75	predators, competition	5.87	54.60
4	4.88	predators, parasites, competition	1.78	36.44
5	3.10	parasites, predators	0.10	3.23
6	3.00			93.10
	(48.28% decrease from parent to new adult)			
		Upper Wasatch		
0	6.00			
1	30.00	competition, weather	19.81	66.03
2	10.19	winter	3.06	30.00
3	7.13	predation, competition	3.07	43.06
4	4.06	predators, parasites, competition	1.46	36.00
5	2.60	parasites, predators	1.26	48.46
6	1.34			95.53
	(77.67% decrease from parent to new adult)			

The rate of reduction for each study plot population is also presented graphically (fig. 5).

The number and occurrence of predators and parasites are shown in figure 6.

Ratios were used in order to equalize the different mountain pine beetle populations and to show the host: predator-parasite relationship by plot. The data is presented as the number (or fraction) of parasite or predator species per one mountain pine beetle. Only species known to be either parasitic or predaceous were accounted for and secondary host insects were not considered for the present time. Graphic presentation of the data is probably clearer than tabular presentation (fig. 7).

Factual interpretation of this data will be difficult until meaningful statistical procedures are developed. Apparent interpretations are possible.

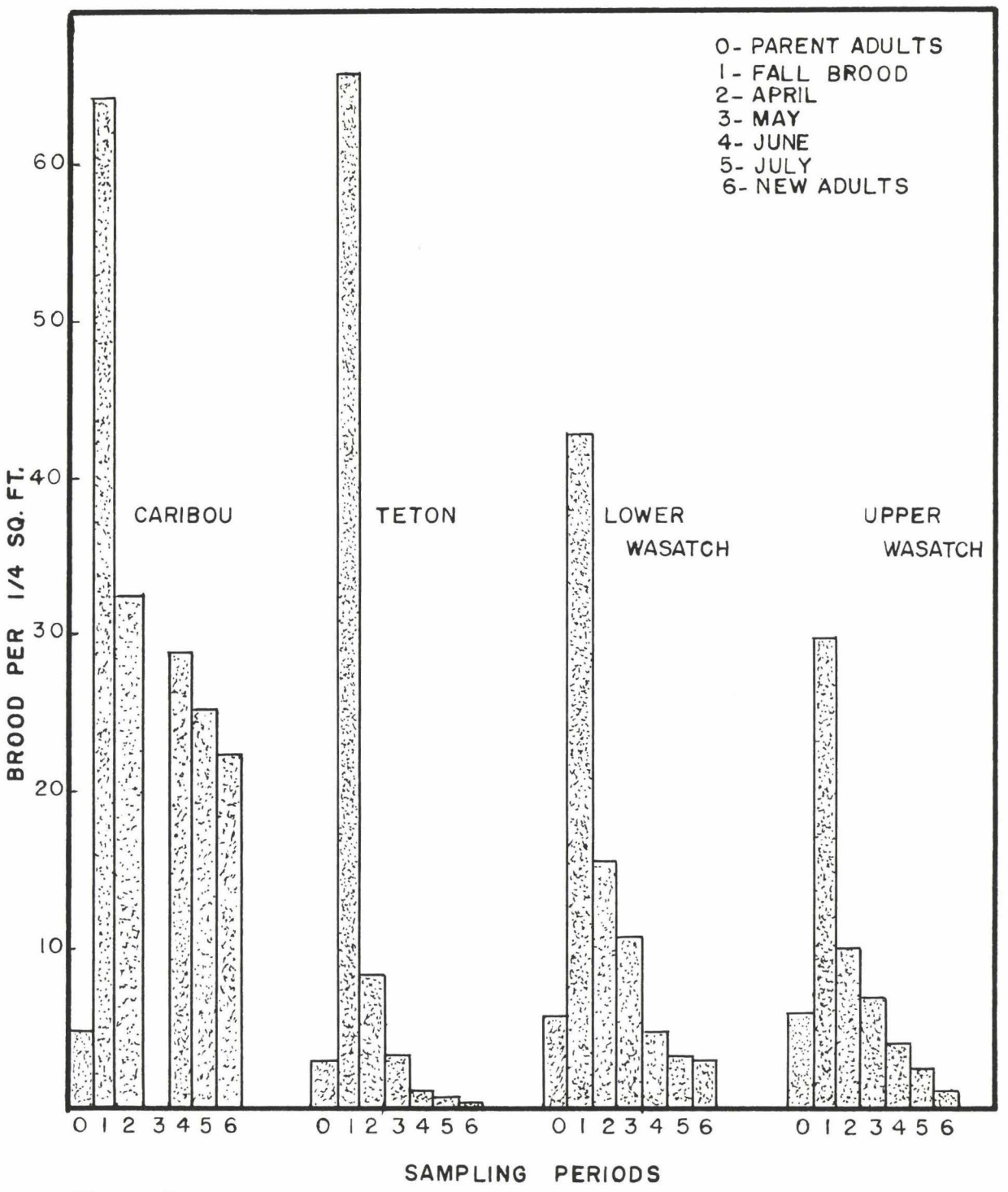
0- PARENT ADULTS
1- FALL BROOD
2- APRIL
3- MAY
4- JUNE
5- JULY
6- NEW ADULTS
BROOD PER 1/4 SQ. FT.
60
50
40
30
20
10
CARIBOU
TETON
LOWER WASATCH
UPPER WASATCH
0 1 2 3 4 5 6
SAMPLING PERIODS

Figure 5

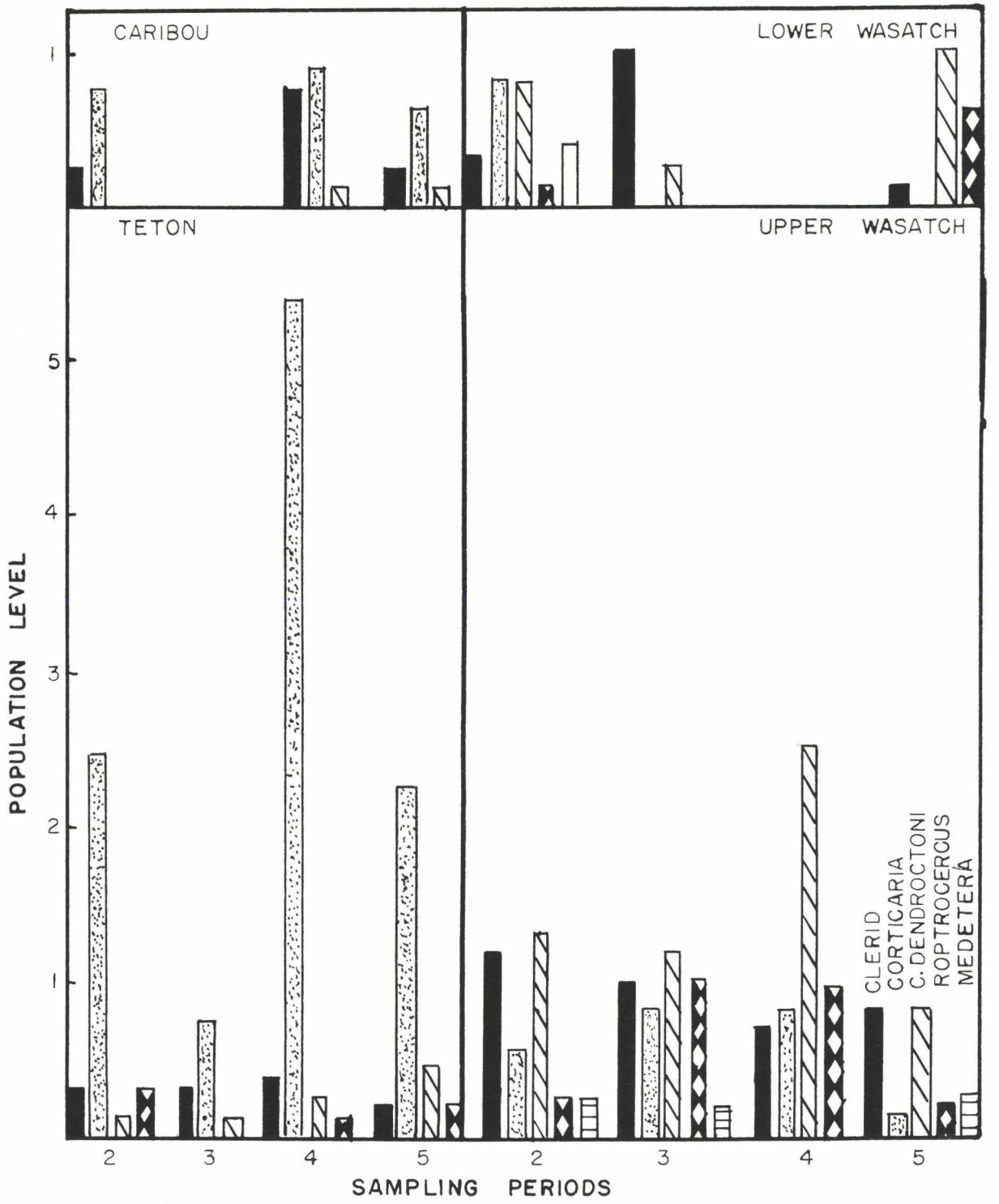
CARIBOU
LOWER WASATCH
TETON
UPPER WASATCH
POPULATION LEVEL
1
2
3
4
5
2
3
4
5
2
3
4
5
SAMPLING PERIODS
CLERID
CORTICARIA
C. DENDROCTONI
ROPTROCERCUS
MEDETERA

Figure 6

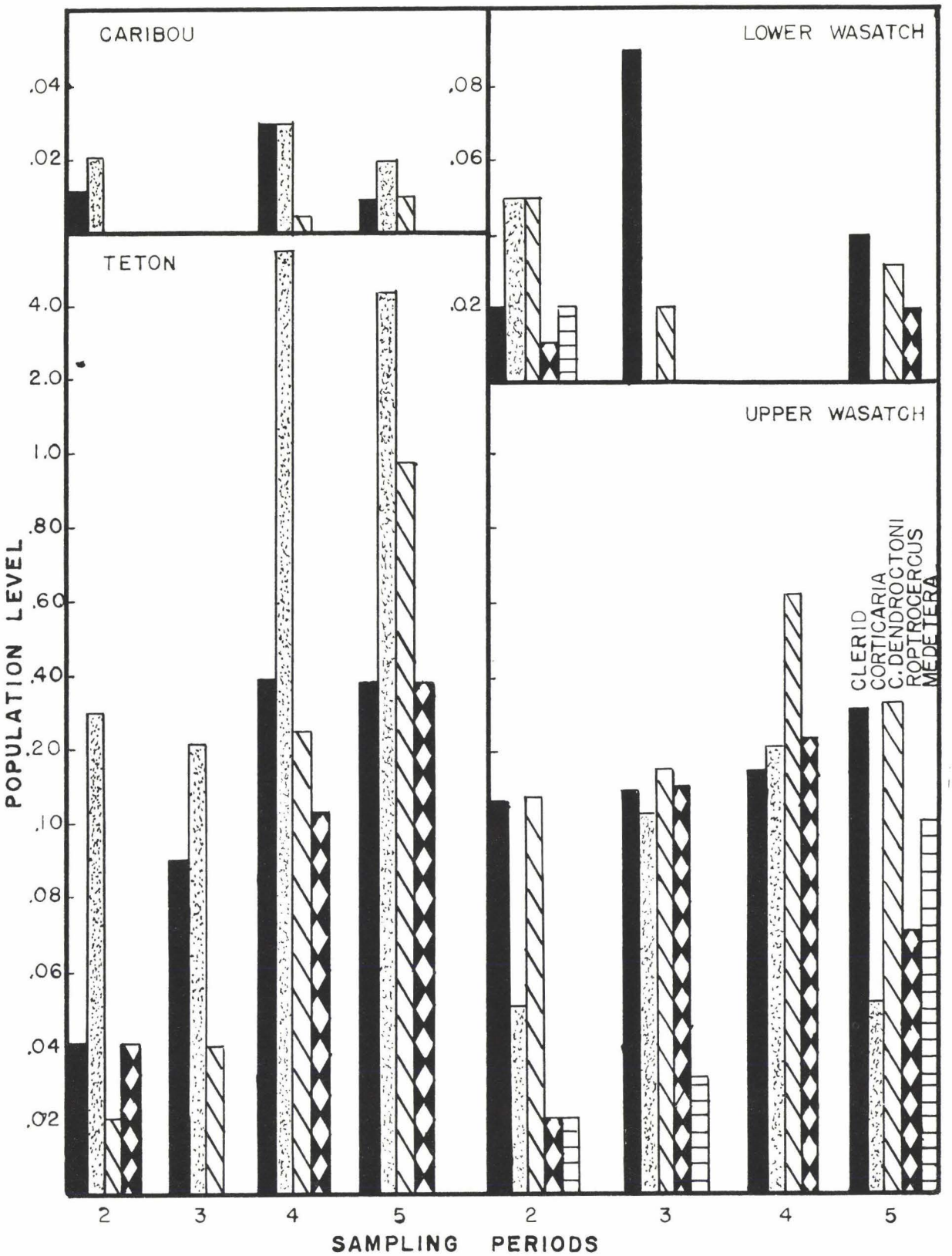
CARIBOU
LOWER WASATCH
TETON
UPPER WASATCH
POPULATION LEVEL
SAMPLING PERIODS
CLERID
CORTICARIA
C.DENDROCTONI
ROPTROCERCUS
MEDETERA

Figure 7

Caribou.--The attack density was slightly higher than for the other study plots, but inches of gallery per attack was about equal to the other populations (table 8). Egg deposition was high. The 50 percent winter mortality was slightly less than the average for two years (60.6 percent excluding Teton, 1962-1963 and 65 percent including Teton, 1962-1963), but with a high pre-winter brood density (64.50) there remained a high spring brood density (32.25). The parasite-predator density or ratio per host insect was too low to cause a significant reduction of brood. This leaves one main influence--competition. For an attack density of 15 per square foot, between gallery competition should produce about 50 percent mortality--in this case 31.32 percent occurred. The host trees on the Caribou plot are characteristically larger than trees on the other study plots, with thicker bark and probably thicker cambium. The difference in observed and expected mortality due to competition was probably offset due to this factor--at least quantity if not quality of cambium.

Table 8.--Attack densities and average inches of gallery per attack for the mountain pine beetle by plot for two study years (based on 1/4 sq. ft.)

	Attack density		In. gallery/attack	
Plot	61-62	62-63	61-62	62-63
Caribou	-	3.75	-	10.52
Teton	1.97	1.56	8.82	10.22
Lo. Wasatch	-	2.90	-	10.27
Up. Wasatch	2.34	3.00	7.99	8.06

Teton.--Again this past year, the attack density was less; inches of gallery per attack was equel and egg deposition was again greater than in the other plots. An extreme cold air movement through this plot was certainly the factor that broke this camel's back--87.30 percent mortality overwinter. The numbers of predators and parasites per sample unit (fig. 6) are not impressive except for Corticaria sp., a probable scavenger. However, the ratio of these factors to the host insect is high (fig. 7), probably resulting from the above average winter kill and subsequent small spring population. In this case, competition was probably of lesser consequence as a single entity. Brood mortality between April and July was 99.28 percent. Expected total mortality due to competition is 58 percent; within brood is 25 percent; and between broods is 33 percent. At a 1:1 ratio of parasites destroying hosts, Coeloides dendroctoni Cush. and Roptrocerus eccoptogastri (Ratz.) accounted for 1.60 of the 8.32

dead brood (19.23%). At a low 1:1 ratio, clerids could have accounted for 1.20 of the 8.32 or 14.42 percent. This would leave 65.63 percent to be attributed to competition, weather, and other factors. More than likely mortality due to predators was much greater than the 1:1 ratio would indicate. It still remains that winter mortality lowered the host population to a level where parasites and predators could exert greater and more damaging influence.

Lower and Upper Wasatch.--These two plots will be compared with each other due to their locations within the same infestation, but at different elevations. Attack densities for the two plots were extremely close (table 8). Elevation and resulting local climate could have produced the shorter galleries and lesser egg deposition on the Upper Wasatch plot--earlier winter and later spring low temperatures. Winter mortality was almost equal (64.80 percent, Lower; and 66.03 percent Upper). At 12 attack density, expected total mortality due to competition is 65 percent; between brood mortality is 46 percent. Mortality between April and July was 80.40 percent (Lower) and 86.85 percent (Upper). This, in numbers of host insects, was a total of 12.31 (Lower) and 8.85 (Upper). However, the parasite-predator population was much less for the Lower than for the Upper Wasatch (fig's. 6 and 7). Possibly competition can explain this occurrence. This could be a case where competition could have been the major force of change on the Lower Wasatch plot, but the large parasite-predator population of the Upper plot lessened the effect of competition and became the major influence. The extreme difference between populations of parasites and predators, by plots, does not logically indicate the rather small differences in pupal (July) populations or emerging beetle populations. In other words, the larger parasite-predator population should have caused a greater mortality than occurred for the Upper plot or the Lower plot should not have shown as great a mortality rate. However, the point is shown clearly that when mortality occurs (sample 5 - Upper Wasatch) is as important as how much--note one half as many beetles emerged on the Upper plot as on the Lower plot - yet up until just prior to emergence, the two populations were relatively equal in numbers (table 7).

Population trends.--Population trends for the three study plots for three attack years and two brood years reveal possible supporting population actions (concentration - dilution) during years of increasing and/or decreasing numbers of infested trees (fig. 8).

The Caribou infestation has definitely increased in numbers of infested trees, yet attack density and brood per sample has decreased. In addition, unless tremendous flight mortality has occurred, much greater numbers of beetles emerged than attacked per sample unit in 1963.

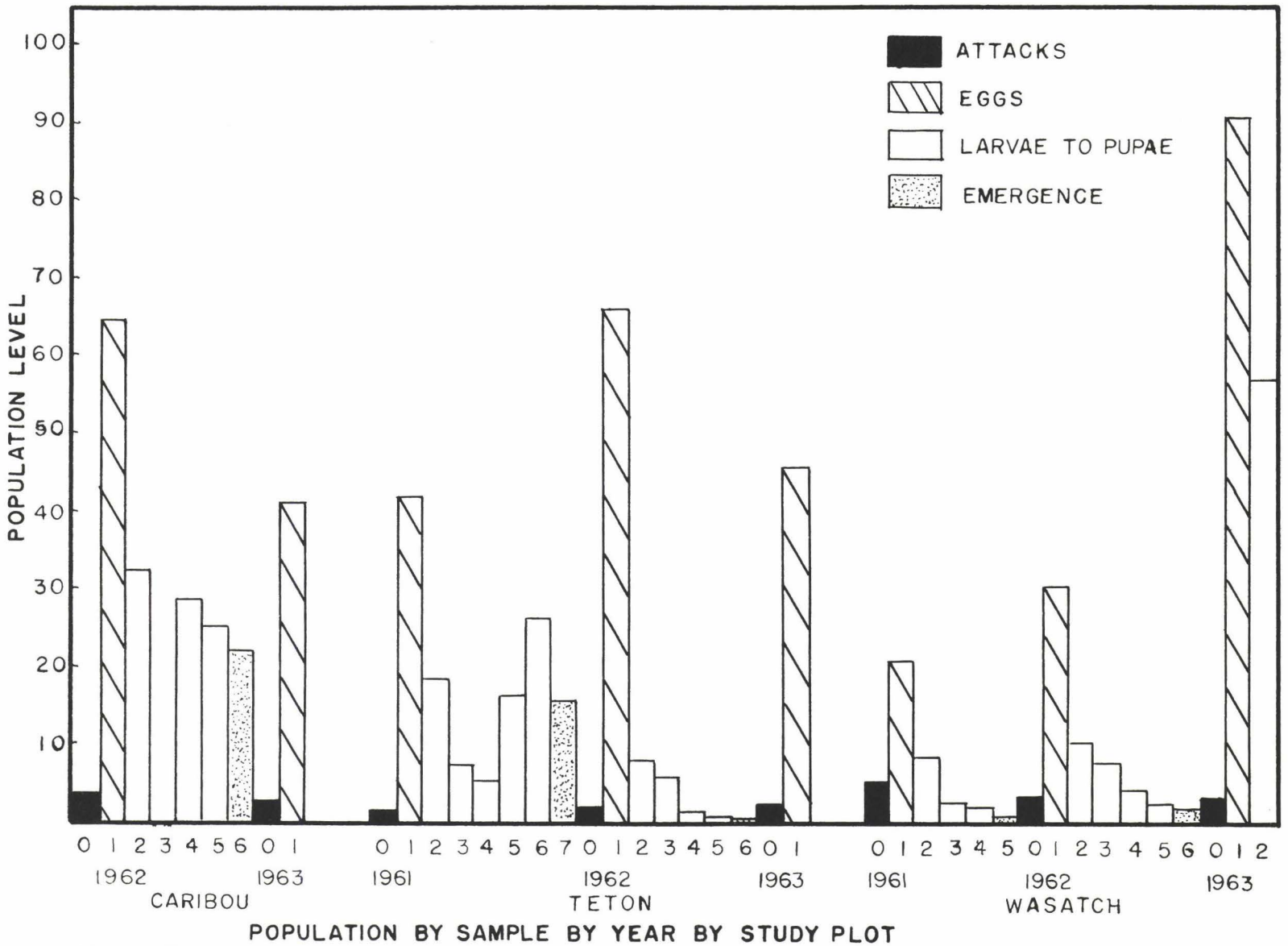
ATTACKS
EGGS
LARVAE TO PUPAE
EMERGENCE
POPULATION LEVEL
100
90
80
70
60
50
40
30
20
10
0 1 2 3 4 5 6 0 1
1962
1963
CARIBOU
0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 0 1
1961
1962
1963
TETON
0 1 2 3 4 5 0 1 2 3 4 5 6 0 1 2
1961
1962
1963
WASATCH
POPULATION BY SAMPLE BY YEAR BY STUDY PLOT

Figure 8

The Teton cannot be discussed at this time for this concept due to the localized catastrophic winter kill, the possibility of beetle flight into the area, and the plot not being representative of the Teton infestation. The number of infested trees increased in 1963 (fall) on the Teton National Forest.

The Wasatch reflects the opposite picture from the Caribou plot. The number of infested trees decreased in 1962 and in 1963. The attack density was greater per sample unit than the preceding emergence for these two years--but brood density has increased. This concentration may indicate less available food but does indicate larger broods. In this case, fewer infested trees do not indicate a lesser beetle population per sample unit--a serious potential of this infestation still remains.

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